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Experimental and clinical results of breast cancer detection using UWB microwave radar

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Introduction

In this paper we present for the first time clinical results of breast cancer detection using a radar-based UWB microwave system developed at the University of Bristol. Additionally, the system overview and some experimental laboratory results are presented as well.

For the clinical result shown in this contribution, we compare images obtained using the standard X-ray mammography and the radar-based microwave system. The developed microwave system has apparently successfully detected the tumor in correct position, as confirmed on the X-ray image, although the compression suffered by the breast during X-ray makes a precise positional determination impossible.

Background

Currently X-ray mammography is the most common technique used in breast cancer screening. It uses ionizing radiation, requires uncomfortable compression of the breast during the examination and is of limited value for younger women. All these limitations of mammography have resulted in research in alternative methods for imaging breast cancer.

Microwave radar-based imaging [1] is one of the more promising candidates and has attracted the interest of a number of research groups around the world. In radar-based imaging, the goal is to create a map of microwave scattering, arising from the contrast in dielectric properties within the breast. The radar approach originates from military and ground-penetrating applications and was proposed for breast cancer detection in the late nineties independently by Benjamin in 1996 [2, 3] and Hagness in 1998 [4].

The University of Bristol team is working on multi-static ultra-wideband (UWB) radar for breast cancer detection. Our radar system is based on the real aperture antenna array. We have also developed a realistic 3D curved breast phantom with appropriate electrical properties. Moreover, our experimental system was built in such way that it can be used directly with real breast cancer patients.

In this paper we briefly present the essentials on the system and some experimental laboratory verification results using a phantom. Then, we present an example of the clinical imaging result with a real breast cancer patient. Our result is compared against the standard X-ray image. To the best of our knowledge, the clinical results of breast cancer detection using radar-based UWB microwave system have never been presented before.

System overview

The developed system is essentially the UWB microwave radar. This radar uses a real aperture array of UWB antennas and operates in a multi-static mode. Antennas are positioned on a section of the hemi-sphere, conforming well to the curved breast shape. For the detailed description of the hardware as well as post-reception focusing algorithms please refer to [5] (first-generation prototype) and [6] (second-generation prototype).

Experimental Setup and Results

During laboratory experiments, the array is first filled with the matching medium, the spherical skin phantom is placed in the correct position, and then we attach a tank to the top of the antenna array to finally fill it with the breast fat equivalent liquid (the same as the matching medium). This setup represents truly three-dimensional (3D) breast phantom. The chest wall is not considered in our experiments.

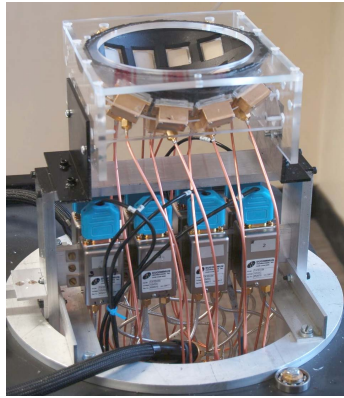


Figure 1. Array, feed and switching (phantom would normally be on top)

In Figure 2 we present an example of the detected 8mm spherical phantom tumor. The obtained image is clear with little clutter and this is typical of our phantom images. More experimental results using the developed system can be found in [5, 6].

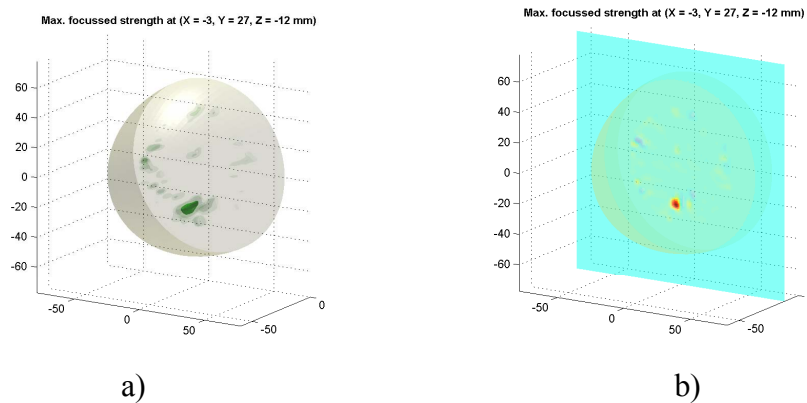


Figure 2. Experimental imaging results for 8mm spherical phantom-tumor located at position $P: x=0, y=30, z=-20\text{mm}$: a) 3D focused image, b) 2D image thru the horizontal plane $z=-15\text{mm}$.

Clinical Setup and Results

The clinical setup and measurement procedure was designed to replicate the phantom setup as closely as possible, as follows. Firstly, the curved array is filled with the matching medium. Then a spherical shell (electrical parameters the same as for the matching medium, and hence essentially transparent) is placed 2cm from the antennas. A small amount of the matching medium is poured into the shell, to provide good contact between a patient's breast and a shell and to avoid any air gaps. Then, the patient lies down on a couch and the array is mechanically positioned with the breast comfortably positioned on the spherical shell. A photo of the clinical setup with a patient (actually a healthy volunteer) in the correct position is shown in Figure 3.



Figure 3. Microwave radar-based clinical setup for breast cancer detection. Patient lying in a prone position.

Using the clinical setup described above, we have performed a small scale blind clinical trial with real breast cancer patients at the Bristol Oncology Center. In Figure 4 below we present the mammogram of the post-menopausal woman with a breast cancer, and a corresponding image using the developed radar-based microwave system. The microwave system has detected the tumor and in the correct position. The estimate of the tumor position between both imaging techniques cannot be precise however, as the breast during the mammography measurement is strongly compressed.

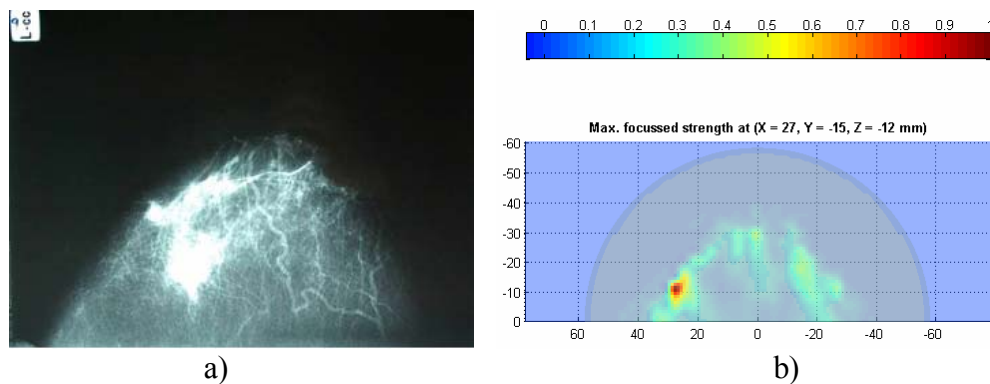


Figure 4. Comparison of the clinical imaging results: a) X-ray mammogram, b) radar-based UWB microwave system (2D slice through a plane with tumor).

The microwave imaging system, which shown essentially a map of scattered energy, provides a three-dimensional (3D) images (unlike X-ray). This gives additional possibilities in analyzing imaging results. An example is shown in Figure 5, where the 3D and 2D images are presented for the same patient as in Figure 4.

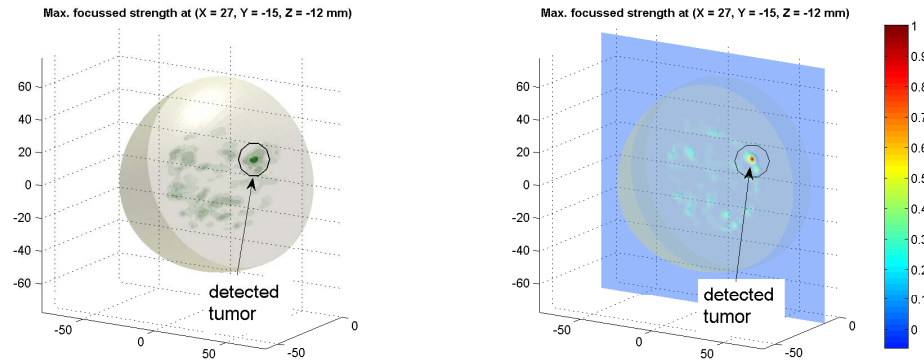


Figure 5. Clinical imaging result using radar-based UWB microwave system: a) 3D image, b) 2D image through a plane where the tumor was detected.

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